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February 14, 1994

William F. Caton, Acting Secretary
Federal Communications Commission
1919 M Street, N.W. - Room 222
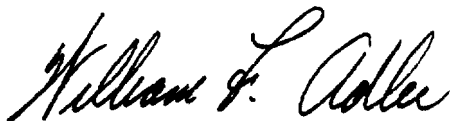Washington, D.C. 20554

Re: PP Docket No. 93-253, Competitive Bidding

Dear Mr. Caton:

On February 14, 1994, Professor Paul Milgrom of
Cornerstone Research and Stanford University sent the
attached letter to Evan Kwerel of the Office of Plans and
Policy with a copy to Professor John McMillan of the
University of California-San Diego. Professor McMillan is
a consultant to the Commission on competitive bidding.
Please include the letter in the official file of PP
Docket No. 93-253.

I am filing two copies of this letter and its attachment
in accordance with Section 1.1206(a)(1) of the
Commission's rules. Please contact me if you have any
questions concerning this matter.

Sincerely,

William F. Adler

Attachment

CC (w/o attachment):
    Evan Kwerel

No. of Copies rec'd_____
List ABCDE

Paul Milgrom
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Phone, fax: (415) 424-8631
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February 14, 1994

Dr. Evan Kwerel
Federal Communications Commission
1919 M Street, NW
Washington, D.C. 20054

Dear Evan:

This long letter serves three purposes. First, I report the results of experiments that Professor Charles Plott ran at the California Institute of Technology ("Caltech") to test the comparative performance of simultaneous versus sequential-combinatorial auction designs. The experimental results do a good job of illustrating the effects that Professor Wilson and I had predicted. Second, I respond to some issues that were raised in the public discussions of the Yale-Anenberg and NTIA-Caltech conferences. Lastly, I respond to the January 9 letter from Professor Robert Weber to John McMillan and you and to the related TDS *ex parte* presentation on January 19.

I am also in receipt of the *ex parte* filing by CTIA, whose representatives met with John Cimko and Myron Peck of the Common Carrier Bureau's Mobile Services Division. This filing appears merely to reiterate CTIA's earlier position, without responding to any of the criticisms that Professors Wilson, McAfee and I made in our respective reply comments. Since they do not address the problems we identified, no additional response appears to be required.

Professor Plott's Experiment

Professor Plott's experiment was conducted at Caltech with funding from Pacific Bell. The great advantage of laboratory experiments over field tests to compare alternative auction designs is that the values that bidders have for the items being auctioned can be controlled in the experiment. Whereas field tests leave open the question of whether any differences in outcomes are due to differences in the bidders' values in the different tests, experimental controls can be designed to eliminate that possibility. That is what was done in these auction experiments.

There were two experiments run: one consisting of sixteen periods of auctions with one auction design and another consisting of the fifteen periods with identical values for the bidders. The auction designs tested were simultaneous and sequential-combinatorial designs. The latter resembles the Bell Atlantic proposal, with "Japanese" bidding rules and a single combinatorial bid. As Bell Atlantic (and CTIA) had proposed, the sealed-bid is opened before the other auctions begin. Also, the experimental design incorporates the possibly unrealistic assumption that the only combination which ever has extra value is the combination allowed under the auction rules. This assumption biases the experiment

in favor of the sequential-combinatorial scheme, adding strength to any conclusion of poor performance of that design.

The experimental design included some environments in which the highest value would be achieved by a single bidder acquiring the whole package of licenses and others in which the sum of the values of individual bidders exceeded the package bidder's value. Each bidder knew only his or her own values for the individual licenses and the combination. When the package of licenses was most valuable, its value was 30% above the sum of the highest individual values. When the package was not most valuable, the sum of the highest individual licenses values was 30% higher than the highest package value. The number 30% is, of course, arbitrary. It was selected to isolate the type of case in which the presence or absence of a combination bid might be significant. A very much higher percentage would make it relatively easy for the package bidder to acquire a network of licenses in any auction design. A very much lower percentage would make it both difficult and comparatively unimportant to accommodate the needs of the potential combination bidder.

Without more detailed knowledge of the actual conditions that will prevail in the PCS auction environment, it is impossible to use experimental outcomes to make unassailable quantitative assessments of the relative importance of different effects. The experimental results are useful, however, for testing the predictions of various experts about the efficiencies and biases inherent in the different designs.

In interpreting the evidence, do keep in mind that there are some significant differences between the experimental design and the actual proposals. First, the experimental simultaneous auctions were conducted in a continuous format, without the sequence of stages and activity rule that Wilson and I had proposed. Second, to simulate the effect of a secondary market, a bid withdrawal rule of the type proposed by Professor McAfee was incorporated in the design. That is, a bidder who withdraws a bid must pay an amount equal to the excess, if any, of his or her bid over the eventual selling price of the license. Third, the environments under study, which involved only nine licenses and only one kind of value interdependency, were much simpler than the environment that would be found in the proposed PCS spectrum auction. Also, the experiment was conducted over a much shorter period of time than we would anticipate for the PCS auction. Finally, there were no professionals present advising the bidders. All of these differences make quantitative assessments tricky. Still, the experiment clearly demonstrates the presence of the biases that Professor Wilson and I had predicted in our two filings in response to the NPRM and that I predicted again at the Yale-Anenberg Conference.

The biases revealed by the experiment were these:

First, when the sequential-combinatorial auction design was used, the package ("combinatorial") bidder was awarded the auction too often compared to the efficient

allocation. Using the sequential-combinatorial rule, in 92% of the auctions in which the package bid should succeed for efficiency, it actually did succeed. However, *when efficiency dictates that the individual bidders should acquire the license because their total values are 30% higher, the package bid still succeeded 53% of time in the sequential-combinatorial design.* This is one bias that we had predicted: the combinatorial bid would often succeed when it should not, and would always succeed when it should, leading the national combination bidder to acquire licenses much more often than is dictated by the criterion of efficiency.

In contrast, in the simultaneous design, when the individual bidders should defeat the package bidder, they did so 100% of the time. When the package bid should win for the sake of efficient allocation, it failed only 24% of the time. According to Professor Plott, half of those failures were due to mechanical problems in executing bidding strategies that were peculiar to the experimental setting. (This is itself a helpful caution about the importance of getting the implementation details right.) Adjusting for these mechanical errors would give only a 12% failure rate, which is probably a fairer report of the performance of the simultaneous auction design in this experiment. Thus, the simultaneous design showed a much smaller bias than was present in the sequential-combinatorial design.

These data are summarized on the first attached bar chart, in which the green area shows the frequency with which the efficient assignment of licenses (individual or package) is made. The yellow area represents failures: either the combinatorial bidder acquiring a package when it should not, or the combinatorial bidder failing to acquire the package when it should. The much larger yellow area for the sequential-combinatorial design illustrates graphically the failures of that design.

Another bias that Professor Wilson and I had predicted was that, in the sequential-combinatorial auction, the bidders at the last rounds would bear a disproportionately large share of the burden of defeating the national combination bid. Once again, the experimental outcomes illustrate our prediction. The most transparent way to view the experimental evidence on this point is to compare the prices in the simultaneous design against that of the sequential-combinatorial design for the first and last items in the sequence. This comparison controls for differences in values among licenses, since the same values were used in both the sequential-combinatorial and simultaneous designs.

The relevant experimental data are presented on the second and third attached charts, based on the fifteen paired auctions. They show that with only one exception, the price of the first item sold in the sequential-combinatorial auction was never higher than in the simultaneous auction. Most often, in the sequential auction design, the first item was sold for a price close to the second highest individual valuation, excluding the valuation of the combinatorial bidder. The pattern of bidding, however, was quite different for the final item in the sequence, where the price was often much higher than the second highest value and frequently also much higher than the price in the

simultaneous auction. As evidence for this, consider the eleven experimental trials in which the simultaneous and sequential prices for the last license differed by more than 5%. In those eleven trials, the sequential bid price was higher in eight and the simultaneous bid price was higher in three. In the eight where the sequential bid price was higher, it was an average of 96% higher than the corresponding simultaneous auction price. By contrast, in the three cases where the simultaneous bid price was higher, it was higher by an average of only 28%. These results indicate that the burden of defeating the combination bid falls disproportionately on the last licenses being sold, as Wilson and I had predicted.

Biases, however, are only part of the story. In the fifteen paired rounds of the experiment, the sequential-combinatorial auction led to higher efficiency than the simultaneous auction on only three. As the fourth attached chart shows, the two designs were equally efficient on five rounds, and the simultaneous auction led to a more efficient allocation of the licenses on the remaining seven rounds. Revenues in the two designs were virtually the same: The sequential-combinatorial auction led to higher revenues in six experimental rounds; the simultaneous auction led to higher revenues on nine. Average revenues in the two designs did not differ in a statistically significant way, but were higher in the simultaneous design. Overall, the revenue differences were slight. The fifth chart illustrates the revenue data.

In summary, data from the Plott experiments are consistent with the Milgrom-Wilson analysis. *First, as we predicted, combination bids in the experiments do create a substantial bias in favor of the national combination bidder, enabling it to win the licenses even when the smaller regional and local bidders are more efficient. Second, again as we predicted, sequential-combinatorial auctions place the burden of defeating the combination bid on the licenses near the end of the sequence, resulting either in inefficient failures to defeat the combination bid or in inequities in the structure of prices paid when the combination bid is defeated.*

Easier Issues Raised at the Conferences
Quite a number of issues were raised at the Yale-Anenberg and Caltech conferences. My comments focus first on four relatively easy ones.

Accessibility to Smaller Bidders
The first easy issue is the concern that a simultaneous auction design might place an onerous burden on smaller bidders who are interested in just one or two basic trading area (BTA) licenses. That concern was echoed in a recent *ex parte* presentation by TDS, where the worry was that small bidders might need to have a representative in Washington throughout the auction to place the daily bids.

In actuality, Professor Robert Wilson and I were well aware of the demands on smaller bidders when we submitted our detailed proposal. Our proposal specifically allows for the possibility that the auctioneer/contractor could, for a small fee, accept remote bids

by fax and provide an electronic data entry service for the smaller bidders. We are not communications experts, so we did not specify exactly what form of secure communications might be used. According to the various communications experts making presentations at Caltech, there are many secure options for remote electronic bidding, and we would expect the auctioneer/ contractor to make a selection that permitted small bidders to submit daily remote bids at minimal cost.

I judge the arrangements mentioned above to be sufficient to remove the burden on smaller bidders. However, if the Commission still has concerns, there are additional provisions one could make to benefit smaller bidders who wish to implement simple, non-contingent strategies. As in other auctions where the physical presence of the bidder is difficult to arrange, our auction design could easily be modified to allow bidders to leave simple bids in advance in the hands of the auctioneer. For example, a bidder who wished to bid up to $10 million dollars for some license could leave instructions to that effect with the auctioneer, and its bids could be entered automatically and programmatically. We omitted this feature in the interests of simplicity. The possibility of leaving instructions forces the auction designer to face the question of how the instructions are to be implemented and what types of contingent instructions, if any, would be allowed. For example, would a bidder be permitted to specify that the auctioneer should bid up to $5 million for the E band in some BTA or $6 million for the F band, with bids to be placed on the F band whenever the difference in current high bids is less than $1 million? What increment would be used, or would that be for the absentee bidder to specify? Absentee, programmed bidding seems to me to be a can of worms that is best left unopened in the interests of limiting complexity and because the remote bidding alternative seems adequate. Still, if there is pressure to do more to ease the daily burden on small bidders, this alternative could be developed further.

Bid Withdrawal

Following the Yale-Anenberg conference in Washington, the economists present discussed the issue of rules governing bid withdrawal. Professor Wilson and I had suggested severe penalties for bid withdrawal in our initial response to the NPRM on the grounds that bids subject to free withdrawal were meaningless and undermined the information revelation that occurs during an auction. However, as others observed, bidders attempting to assemble a package of licenses might want to be able to withdraw their bids if their attempt were to fail, and they might be reluctant to bid aggressively if bid withdrawal were too heavily penalized. At that meeting and later in an *ex parte* filing, Preston McAfee suggested a less severe bid withdrawal penalty. Specifically, he suggested that the bidder be required to pay the difference between the withdrawn bid and the final selling price of the license, in an amount not to exceed the bidder's deposit. Assuming the use of a substantial deposit, this seems to me to be adequate to discourage insincere bids. With a small deposit, however, this rule is similar to the rule of free bid withdrawals and could result in mischief.

Tie Bids

In our filing, Professor Wilson and I observed that we had left some minor details unspecified. In particular, we omitted any discussion of tie bids. This is a minor detail, but since it was asked about, please allow me clean it up. If a sequence of sealed bids is used, then I propose that ties be broken according to the time stamp on the bid, with the earlier bid being declared the high one.

If this seems arbitrary, let me remind you that the only substantial consideration in a tie-breaking rule is administrative simplicity. A bidder who is concerned that a bid of $5,000,000 might lose due to a tie can choose to bid $5,000,002 instead. The strategic significance of a tie-breaking rule is trivial and the rule just given is easy to administer. Nothing more complicated is required.

Field Tests

Another issue that was raised concerned the appropriateness of field testing the few leading designs to see which design performs best. At the Yale-Anenberg conference, Professor Paul MacAvoy, dean of the Yale School of Organization and Management, spoke out against any plan to conduct field tests, citing the history of earlier government experiments, such as the income maintenance experiment. I concur with Professor MacAvoy. The results of such tests have always been ambiguous and, as Professor MacAvoy explained, are so for predictable good reasons. Let the FCC staff recommendation be made now based on the scientific record, without introducing the random element of field testing into an already complex decision.

Value Interdependencies and Related Issues

The "Non-existence" Problem

Unfortunately, not all of the auction design issues are so easy as those discussed above. One vexing and fundamental issue, which was raised by Professor John Ledyard at the NTIA-Caltech conference, is this: There is a theoretical possibility that there don't exist what economists call *"competitive equilibrium"* prices for the individual licenses. Competitive equilibrium prices are prices at which supply equals demand, which in this case means prices such that exactly one bidder wants to buy each license. For the sake of interested non-economists who may read this letter, the next four paragraphs provide a further elaboration of the non-existence problem and its significance for auction analysis.

In a typical oral auction for a single item, prices initial start low enough that several bidders would want to buy the item at that price. During the auction, the price gradually rises to the point where only one bidder wishes to buy the item. The price established by the auction is what we call a competitive equilibrium price. It is so called because it sets the demand for the item to one unit, which is also equal to the supply. The auction itself is usefully construed as a means of discovering the competitive equilibrium price.

When there are several items for sale with value interdependencies, finding appropriate prices is more difficult. The price that a buyer would be willing to pay for one item may depend on the prices of the others. For example, a bidder might be willing to pay more for a license for Southern California if it also holds a license for Northern California. To see why this can complicate the problem, suppose we start from bid prices where there is more than one bidder still interested in buying each license and we gradually raise the bids for the Southern California license. As that bid rises and while there are still several active bidders for the license, there may come a point where there are no more bidders for the *Northern* California license. Unlike auctions for a single license, raising the price for one license not only diminishes the demand for that license: it may also diminish demand for others. (The same effect can arise when bidders face a budget constraint.)

All that this example illustrates is that some particular way of finding prices by bidding may fail to identify prices at which supply and demand are in balance. One might still hope that some other design could perform well enough to solve the problem. However, if the value interdependencies among licenses are sufficiently strong, there may be no prices at which precisely one buyer wishes to acquire each license. In more technical terms, there may not exist any competitive equilibrium prices.

If competitive equilibrium prices do not exist in the PCS auction setting, that could pose a substantial dilemma for the auction designers. All open auction designs are traditionally conceived as mechanisms to search for competitive equilibrium prices. Standard economic theory indicates that the allocation resulting from an auction is efficient when the auction mechanism succeeds in finding such prices. The standard theory provides no general guidance about the performance of auctions when competitive equilibrium prices do not exist, but experimental evidence suggests that auctions may attain reasonable levels of efficiency in *some* of these environments.

The NTIA-Caltech Design

As you may know, I have been a leader in studying the problem of when prices are an effective mechanism for resource allocation and when other mechanisms should be preferred. Professor Ledyard opened his own discussion of this topic at Caltech by citing chapters 3 and 4 of my textbook *Economics, Organization and Management* (Prentice Hall, 1992, coauthored with Professor John Roberts). The key point is that when the competitive equilibrium prices do not exist, no system that relies on prices to guide decisions can guarantee an efficient combination of licenses. Consequently, as explained in the textbook, other kinds of designs involving more intensive communication may be more effective. Failures of existence of the competitive equilibrium provide the strongest

theoretical case for considering designs that use much more than simple price information, such as the complicated combinatorial bidding scheme suggested by NTIA, provided the proposed design is ready, practical and operable.

These observations suggest two questions: First, are the combinatorial schemes ready, practical, and operable? Second, is the theoretical problem that Ledyard identified to motivate this more complex resource allocation scheme a significant one for PCS auctions?

Regarding the first question, I saw nothing at Caltech that would alter the assessment that Professor Wilson and I made in our initial response to the NPRM: unlimited combinatorial bidding for all 2562 licenses is too complex, too difficult to administer, and too opaque to the bidders to be attractive options. With 2562 licenses, there is a virtual infinity of possible combinations. Unlimited combination designs may possibly be attractive challenges for the mathematically gifted Caltech students, but they are not practical for the businesspeople who will want to exercise control given the sums at stake. Moreover, although the software to conduct such auctions on a small scale is now nearly in place, the software for large scale combinatorial designs is not, and might never be, due to the difficulty of the problem.

As Professor Wilson and I argued in our NPRM comments and as the Caltech researchers have acknowledged, the problem of building an algorithm to evaluate combinatorial bids in general is a particularly hard one. In the language of algorithm builders, as Ledyard explained, the problem is "NP complete." This means it is as hard as such famous problems as the "traveling salesman problem," which has been studied for decades and for which no really efficient general algorithm yet exists. I do not wish to exaggerate the problem. As Ledyard further explained, if one knows enough about the auction environment and the kinds of combinations that are most plausible, it may be possible to construct a specialized algorithm that is tailored to the particular setting. But there is not yet even an approximate agreement on which combinations are appropriate and, in view of the restrictions imposed on cellular carriers, the desired combinations are certain to have complex, overlapping structures. No proposal has been made and no algorithm devised to deal with such a problem, and that must be counted as a strong negative factor.

Complexity is just one undesirable attribute of the NTIA-Caltech design. A second is that the use of combinatorial bids and the standby queue provide a whole range of unexplored strategic opportunities for the bidders. Ledyard himself identified one weakness of the mechanism: bidders could "flood the queue" to inhibit its operation. There may be other as-yet-unidentified strategic opportunities as well, and new possibilities may be introduced by attempts to correct the known problems. Bidders with hundreds of millions or billions of dollars at stake and expert consultants to advise them are likely to be clever in finding ways to exploit a complicated bidding system like the one NTIA proposes.

Finally, questions have been raised about the legality of the NTIA mechanism. The standby queue explicitly encourages communications among bidders in the fixing of prices. As Ledyard reported, the mechanism works best when additional informal communications among bidders are also encouraged. Regardless of how well intentioned such communications may be, it does risk running afoul of antitrust laws.

Regarding the second question, the Caltech researchers illustrated convincingly that their theoretical concerns can have practical importance when the application is bidding for rights to use a stretch of railway track at a particular time. But is it of practical importance for PCS auctions? There is nothing I have seen in the written record to suggest one way or the other that competitive equilibrium prices will exist in PCS auctions, but there *is* reason to think that the problem of packaging in railroad scheduling is much more severe than any similar problem that could arise in the PCS auctions.

In the railroad problem, where the licenses provide rights to use track in a particular time slot, what Professor Ledyard called the problem of *"fit"* looms especially large. This is the problem that a license to use a track between, say, 3 P.M. and 4 P.M. daily for a freight train is literally valueless to the freight company if the trip takes two hours unless the company can also acquire a license to use the track between 2 P.M. and 3 P.M. or between 4 P.M. and 5 P.M. That is, the time slots have to *fit* together *exactly* to have any value at all. When the problem of fit is present, a bidder trying to acquire the licenses one at a time runs the risk of getting stuck with some worthless combination. This is problematic for both sequential and simultaneous designs.

Positive Value Interdependencies in PCS Systems

While there certainly are value interdependencies among licenses in PCS auctions, nothing that is exactly analogous to the problem of fit in train scheduling is likely to arise. The positive value interdependencies ("complementarities") in the PCS setting arise from such things as (1) provision of roaming services, (2) interference at geographical boundaries, and (3) economies of scale in technology and marketing arising primarily from spreading of fixed costs. Roaming can substantially increase the value of PCS services for some customers. However, as the history of cellular telephony has proved, roaming services can be provided by agreements among carriers even without unified ownership of all the geographic licenses. The severity of potential radio interference at geographical boundaries is hard to assess. In many cases, the boundaries lie in low population density areas and are not a serious concern. In others, agreements between nearby carriers can resolve most of the problem. None of the three sources of positive value interdependency would suggest that if one license is missing from a package, all of the system value is lost. Finally, in the real auctions, in contrast to many of the Caltech experiments, bidders will have the option of using the secondary market to dispose of unwanted licenses. The secondary market reduces the auction risks faced by a bidder who places a much higher value for an extensive network than the sum of the values of the individual licenses. (Experiments with appropriate bid withdrawal rules, like the Plott experiments reported earlier, are immune to this last criticism.)

Nothing resembling problem of "fit" described above for the case of railroad scheduling has been documented in the record for PCS licenses, and nothing in the general nature of PCS services suggests that this problem should loom large. A general concern about the problem of "fit" should hardly be enough to dissuade the FCC from pursuing a simple auction strategy. One could, after all, raise the same general concern for any markets, so the general argument is an argument for the wholesale abandonment of the price system for resource allocation. Moreover, the remedies that are called for by those who fear the problem of "fit" are so novel, complicated, and relatively untested that they pose a risk of disastrous failure in their own right. Much more of a record ought to be required before seriously considering such schemes.

Lessons from the Caltech Demonstration

The auction demonstration conducted at Caltech was interesting, and for me served mainly to confirm my sense of how complex the NTIA design is. Unfortunately, little else bearing on the PCS sale could be gleaned from the demonstration, due to a flaw in the design of the demonstration. Although the general structure of the environment for the demonstration experiment was specified by the NTIA, the details were specified by Caltech faculty members Ledyard and Porter, who at the conference explicitly eschewed any knowledge of the actual environment of the PCS auctions. As one might expect, the researchers incorporated features from the situations they do know about, such as railroads and space stations, in which the fundamental pricing problem is prevalent. As reported at Caltech, the experimenters arranged for a large additional premium to be available to a bidder who assembles a specific package of licenses, but that the premium is zero *if even a single one of the licenses in the package is not acquired*. Moreover, the auction designs tested omitted important details of the design we had proposed although, to be fair, they did also incorporate some of the relevant design features.

I am not alone in my skepticism of what could be learned from the demonstration. Caltech Professor John Ledyard closed the conference by declining, in response to your direct question, to make any recommendation about the best auction design for PCS. He remarked, quite correctly, that the best design depends on the detailed circumstances of the auction. I agree wholeheartedly, and would add that whatever design is eventually implemented should be one that has been subjected to a long enough period of critical analysis to ensure that its flaws have been revealed.

Professor Ledyard went on, in response to my follow up to your question, to assert that the full set of experiments does say something about designs that should *not* be adopted: there are no circumstances under which sequential auctions is ever a preferred design when there are some value interdependencies. According to Professor Ledyard's summary of the Olsen-Porter experiments and as Professor Wilson and I had predicted, *simultaneous auctions perform better in experiments than sequential auctions*. The sixth and last attached chart shows the Olsen-Porter data, in which the superior performance of the simultaneous design is quite clear.

Robert Weber's Letter

Finally, I turn to the letter by Professor Robert Weber criticizing the Milgrom-Wilson simultaneous auction proposal. The letter is surprising for two reasons. First, Professor Weber was himself an advocate of simultaneous auctions last summer, but now has changed his position. Second, Weber's approach to criticizing our design uses the outdated method of comparing our design to some unachievable ideal, rather than to other designs that might actually be implemented. There are some shared limitations that are inherent in every auction design, including the limitation that the prices cannot all be finalized before the bidders make some firm commitments. It makes no sense to criticize our design alone on such grounds. As I shall argue below, on each of the criteria that Weber describes, our proposal is superior to the proposed sequential auction alternatives.

Weber raises three main points. Let us consider them in turn.

Bidding With Complementarities

First, just as Weber alleges, sufficiently strong complementarities (positive value interdependencies) do create a problem for our auction design, but the problem is even greater when the licenses are sold in a sequence of auctions as he proposes. In a sequence of auctions, how is a bidder to know at the first stage whether to acquire the first component of the package? If the bidder buys the first component and later quits, the bidder will wind up with what Weber calls an "illogical (uneconomic) package of items." The bidder could alternatively decide to stay in the auction even if the prices of the later licenses are so high that no profit can be earned, because the expenditures on the early purchases are sunk costs. In that case, there is still an uneconomic packaging of the licenses. These are qualitatively the same kinds of outcomes whose possibility Weber criticizes as a defect of the Milgrom-Wilson proposal.

Weber suggests that with a sequential design, the bidder will at least be certain about the allocation of some licenses when bidding on the last licenses in the package. That is true, but small comfort when the bidding on the first licenses begins. It is a fact about every auction design that the full set of prices cannot be known until the last item is closed. It is also a fact that the simultaneous design is the only one that permits the bidders to obtain substantial information about all the prices before any of the licenses is finally assigned and the only one that permits bidders to execute back-up strategies after substantial information has been revealed. I will argue these points in more detail in the next section.

Professor Weber raises the issue of bid withdrawal when an uneconomic package has been formed. His discussion again focuses on our simultaneous auction proposal, but one must also ask: What will happen in a sequence of auctions when a bidder, having acquired the first component of the package, learns that the other components are too dear? Should the bidder be permitted to default? At what penalty? Should the unwanted license be subjected to a new auction? Weber's implicit suggestion that these points are

uniquely problematic for simultaneous auctions is wrong.

At this point, Weber introduces as "anecdotal evidence" his own personal experiences in the single demonstration experiment at Anenberg, and concludes that this supports his conclusions about the advantages of sequences of auctions. This was a demonstration experiment which the designers explicitly declared might be useful for analyzing process but could not be useful for analyzing outcomes.

One needn't rely on anecdotes. There have been experiments designed to analyze outcomes — including those conducted at Caltech at the NTIA's request. The Caltech experimenter, Professor John Ledyard, summarized the evidence as saying that *sequential auctions lead to less efficient outcomes than do simultaneous auctions*. Undocumented evidence of one bidder's experience in one demonstration experiment which was not designed for comparing outcomes is inadequate grounds even to contest, much less reverse, the experimenter's scientific conclusion.

Revelation of Information During the Auction

Second, Weber disputes the Milgrom-Wilson-McAfee contention that useful information is revealed during the conduct of the simultaneous auction. He writes that the Milgrom-Wilson proposal, in particular, "bring relatively little meaningful information into the public domain until near the very end." The phrase "near the very end" makes the statement too vague to be incontrovertibly false, but it is suffices to point out that the information in our design is revealed soon enough to be useful for decision making. Every day in our design, the current high bids are lower bounds for the final prices. Bidders hoping to acquire individual licenses or packages of licenses can and will use that information to decide when to drop out. A bidder who might otherwise have bid aggressively for the B band in the metropolitan New York City MTA as part of a national license may drop out of contention for that license if the bids in the Los Angeles-San Diego MTA and the Chicago MTA become too high. Moreover, as the activity ratchets down in our auction, bidders are guaranteed that it cannot ratchet up again. The reason is that, according to our activity rule, bidders who cease to bid actively in the late stages of the auction cannot become active again. If the prices in one of these regions escalates slowly, then a bidder who is interested in a national combination can protect itself and satisfy the activity rule by bidding for the low-priced license first.

Rather than making abstract statements about information, however, let us turn to the relevant comparison. In the sequential auction design, if a New York MTA band is sold first, the bidders have *absolutely zero information from competitors' bid about the likely prices for the other licenses*. While it is true in a sequential design that a national combination bidder, for example can know precisely what the prices of other licenses will be when it bids in the later rounds, it is then too late. The bidder in our example is already committed one way or the other. It has either bought the New York City license and committed itself to continuing on to acquire a national combination, or it has refrained and must watch from the gallery even if the prices of other licenses are lower

than it has forecast. It is the simultaneous auction that incontrovertibly gets the most information to bidders while they still have a chance to use it.

Professor Weber also laments the possibility that in a simultaneous auction, some bidder may make a preemptive bid, on the grounds that it impedes the information flow. That argument hasn't been thought through. Presumably, what Weber calls a "preemptive bid" means a bid that is unexpectedly high, thereby yielding useful information to the other bidders.

Weber also writes that a bidder might exploit the 5% bid minimum increment to "freeze out competitors." Presumably this means that a bidder might bid within 5% of another bidder's value, thereby blocking a higher bid by a bidder with a higher value.

What Weber has not explained is why this scenario should be a concern for the FCC. Let us first examine the simplest scenario, in which there is but a single license for sale. Suppose that a preemptive bid succeeds in winning some license and earning a profit for the bidder. For that to happen, it must be that no other bidder has a value more than five percent higher than the bid. In that case, though, the license has been assigned efficiently or nearly so. If the assignment is inefficient, then the resulting price is *at least* ninety five percent (95%) of the *first highest value*! There is hardly reason to fear a scenario such as that.

Such efficient preemptive bidding, however, is not likely to occur in a simultaneous auction. One reason is that a bidder would be most unlikely to be able to estimate another's value to within the required five percent tolerance. Another is that preemption is a self-defeating strategy in an environment where there are good available substitutes. To illustrate, suppose that the A and B bands in the Chicago MTA are perfect substitutes. Imagine the embarrassment of an executive who bids preemptively for the A band in Chicago only to find that the equivalent B band sells for a much lower price. If, on the other hand, the price of the B band does rise to same level as the A band, then the preemptive bidder has gained nothing. The early high bid will not protect it from the competition.

In his *ex parte* presentation of January 19, Professor Weber raises the opposite objection to simultaneous auctions: bidders may confound the auction by "laying back," thereby preventing the prices from revealing enough information about the underlying values. Actually, however, bidders won't be able to lay back in the Milgrom-Wilson design: our activity rule limits the ability of inactive bidders to suddenly reenter the auction.

Weber's *ex parte* presentation for TDS on January 19 contains the seeds of the explanation of his position on these informational matters. As the filed document describes, TDS's values for its licenses will depend on the identity of its competitors. TDS would naturally like to know those identities and the prices that others have paid

before it has to begin to bid. A sequential design with the MTA licenses sold first would achieve that end.

In addition, if the FCC adopts TDS's recommendation of a sequential auction in which combination bids beyond the MTA level are not permitted, that would create a difficult bidding problem for the larger bidders. They would have minimal bid information to rely on when the largest commitments had to be made in the first few rounds of the auction, making the final allocation the result of simple guesswork. Such a design would maximally disadvantage those seeking to assemble large networks of licenses, consistent with the objectives expressed in TDS's initial comments on the NPRM, in which it was argued that the FCC ought to bias the auctions against nation-wide licenses.
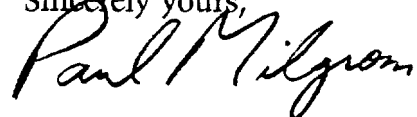
Administrative Fragility
Finally, Weber claims that the Milgrom-Wilson design is administratively fragile, based on incorrect speculation about the details of our implementation. Indeed, he opens his third point with the sentence: "I didn't hear any specific discussion of how daily bid submissions will take place." *In fact, however, Wilson and I have been quite specific about the details of how our design would be implemented.* We have even provided spreadsheet software to illustrate how bids would be prepared by bidders and processed by the FCC. It's available for the asking.

Every point that Weber raises in this administrative fragility category was addressed in our earlier filings. I won't repeat our arguments here. Our filing included specific procedures for checking diskettes. We anticipated that, despite all the safeguards, there will be a need for handling occasional exceptions in case bidders have a problem meeting one day's deadline. Our proposal, by design, is unaffected by occasional minor administrative failures. For example, contrary to Weber's assertion, it simply isn't true that in our design there is a strong "likelihood that some bidder will internally do something `wrong' during the auction and face dire consequences." We explicitly included an automatic waiver rule that allows a bidder to miss occasional bid deadlines with no consequences whatsoever. In short, quite the opposite of Weber's assertion is true: *the Milgrom-Wilson design is administratively robust.*

This letter has grown to be longer than I had originally intended. I hope you find it helpful. I have tried to be fair in my assessments, but it does seem to me that the critics of the Milgrom-Wilson design have not made their case, and that the other designs proposed in writing all have well-identified and serious flaws.

Please feel free to contact me at (415) 723-3397 if you would like clarification of any of the points that I have raised.
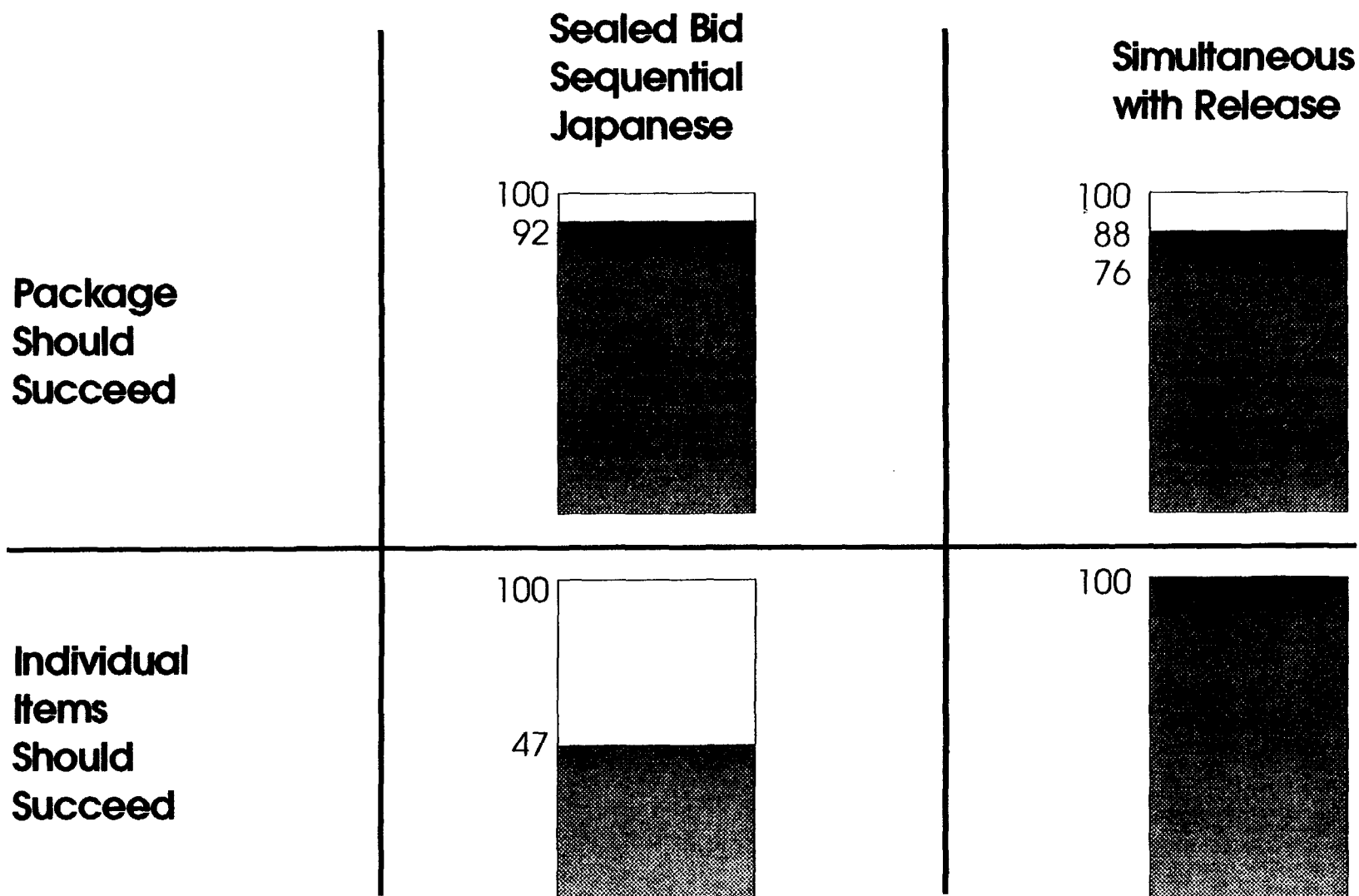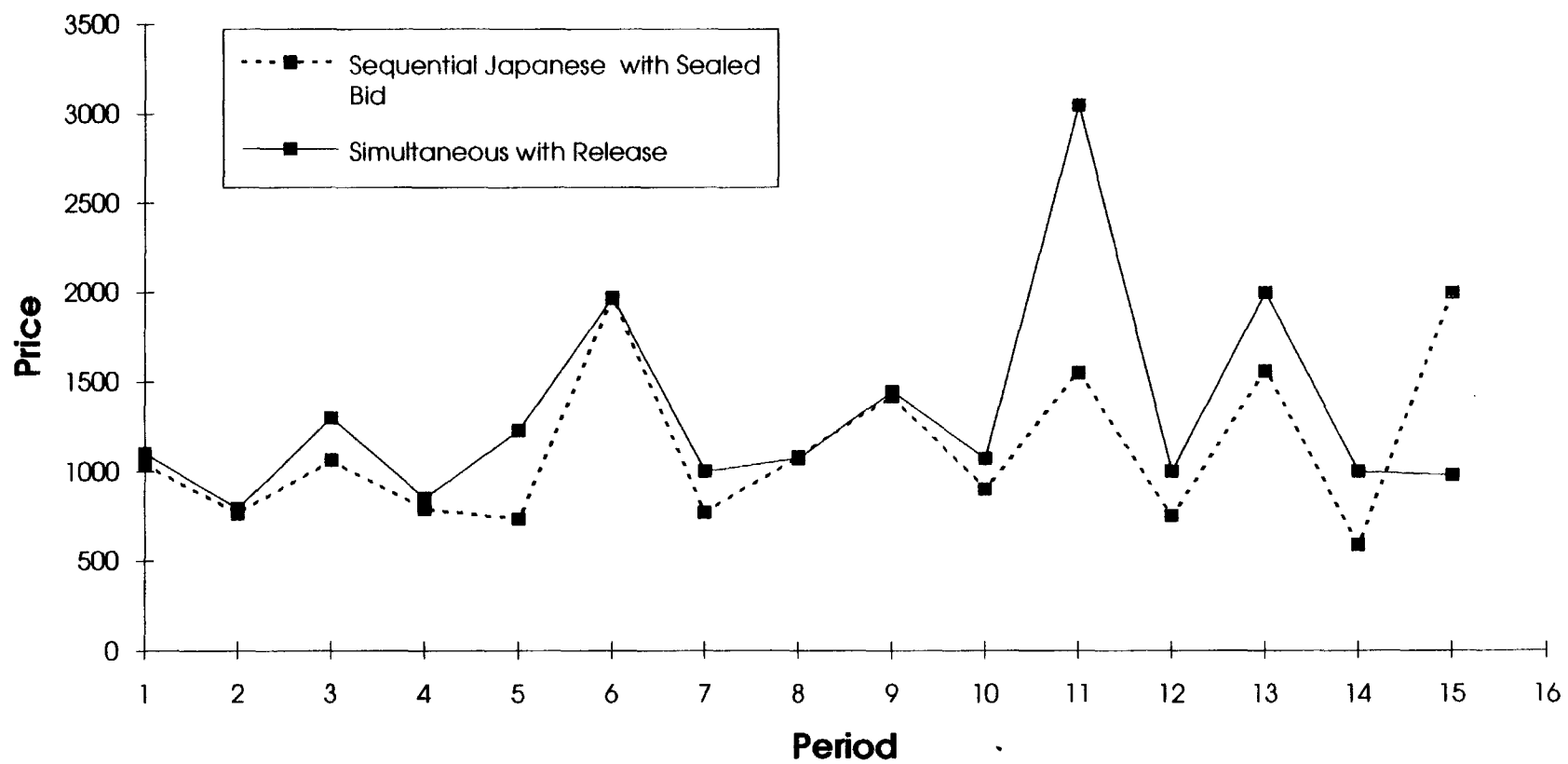
Sincerely yours,

Paul Milgrom

Sealed Bid Gives an Advantage to The Package

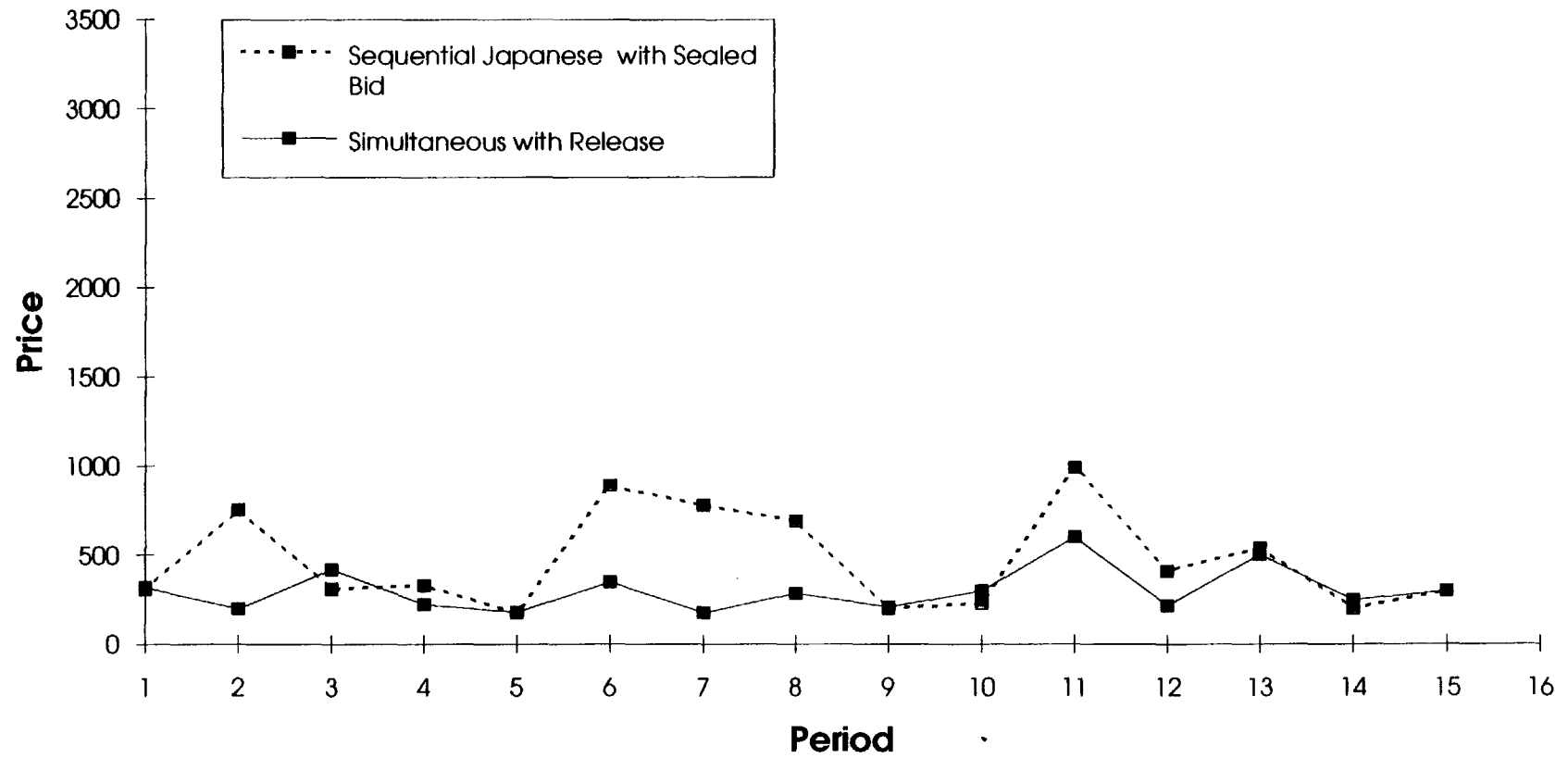## Success Rates of Package Assembled vs. Individual Items

Pooled Data: Percentage of All Periods

Price of First Items Auctioned:
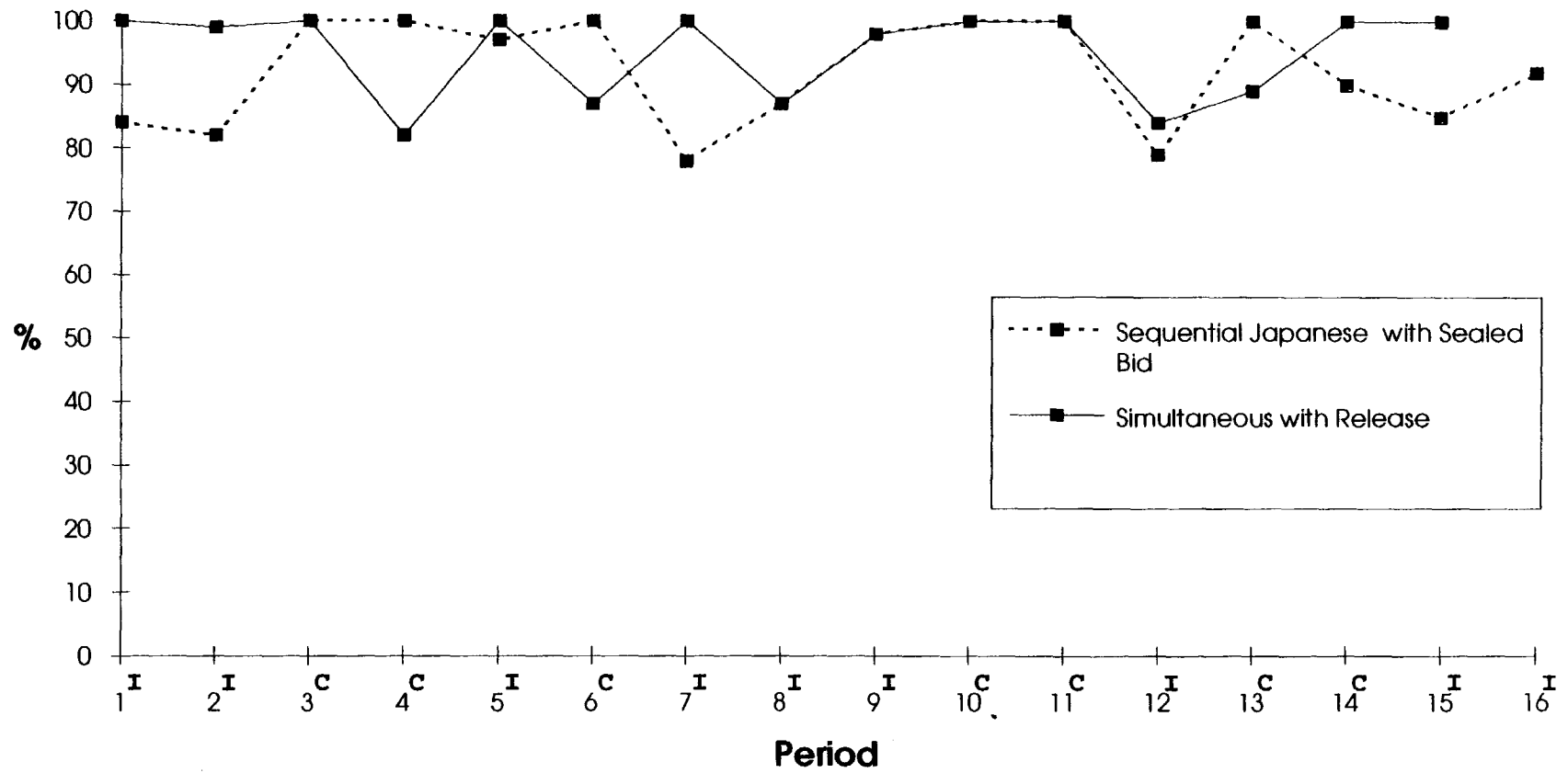**Simultaneous Is Higher**
(reflecting the high value of first units)

Price of the Final Items Auctioned:
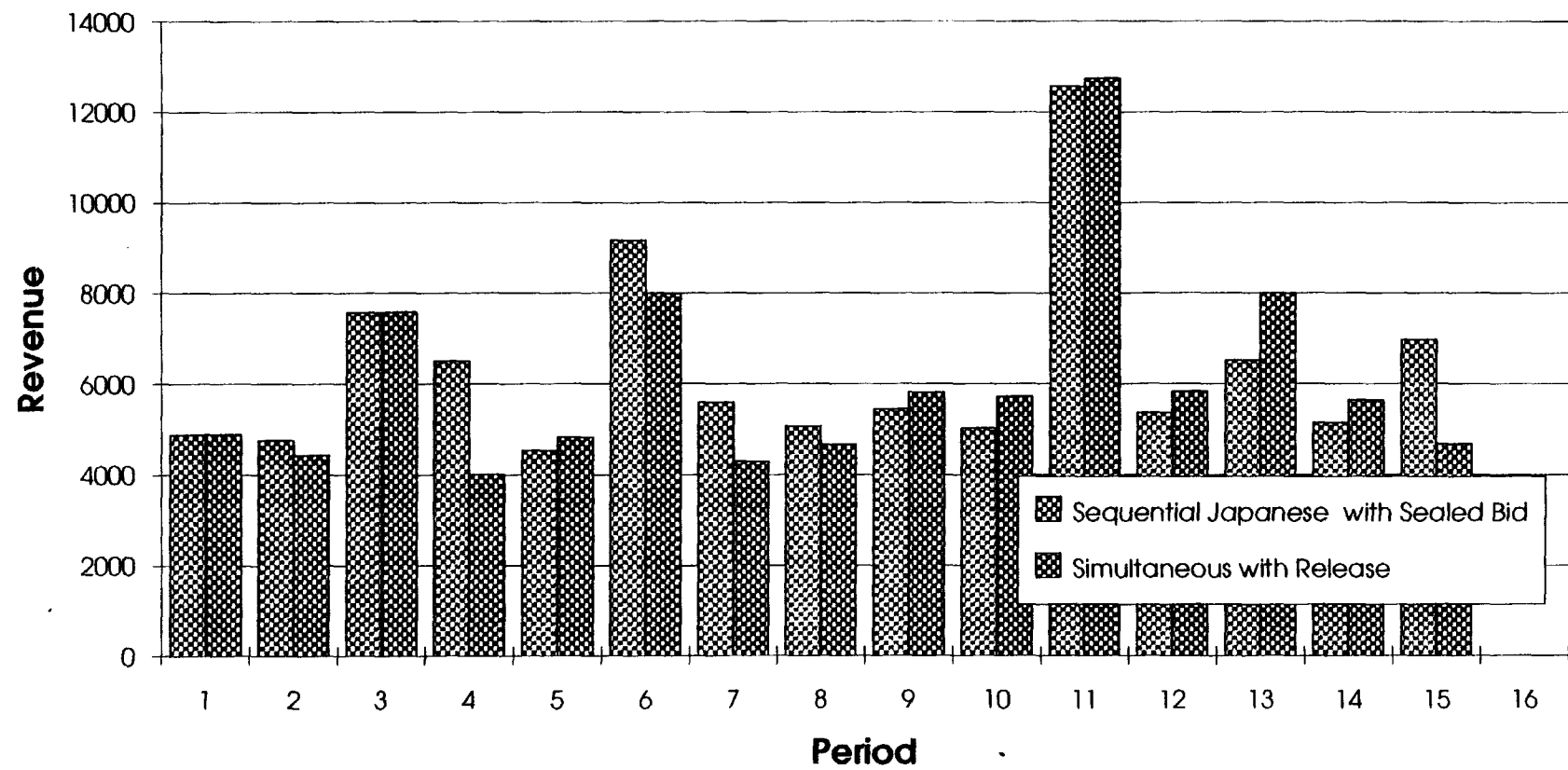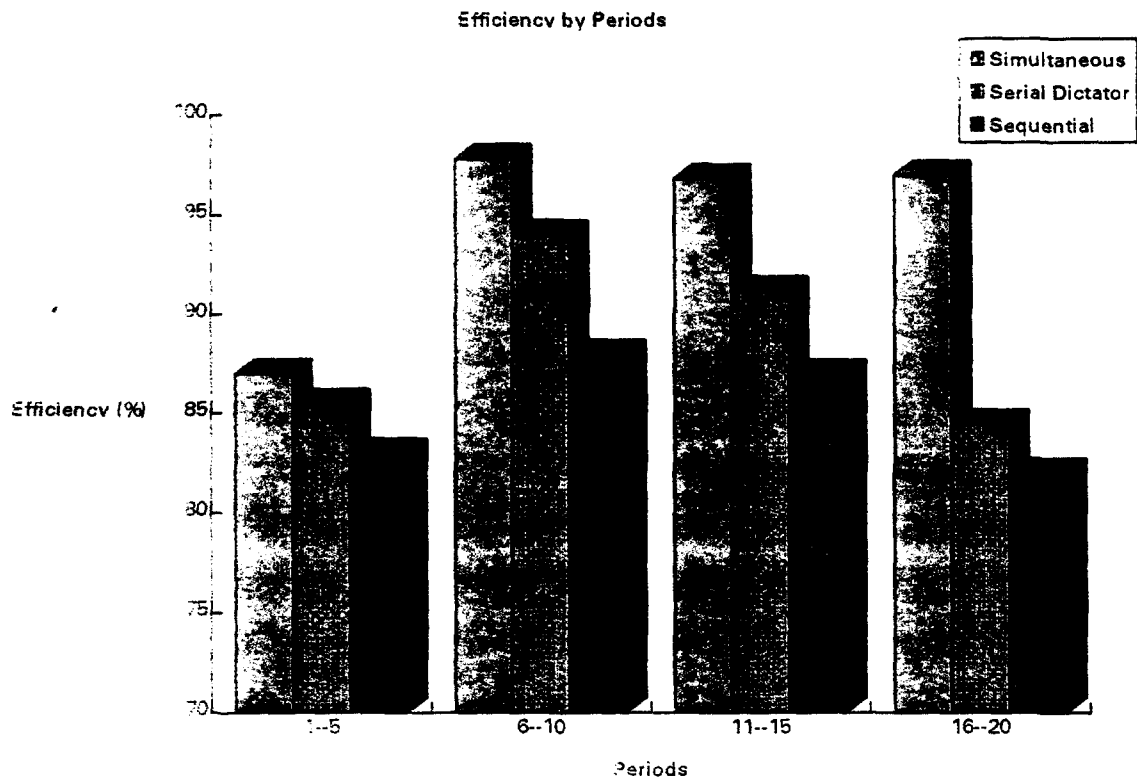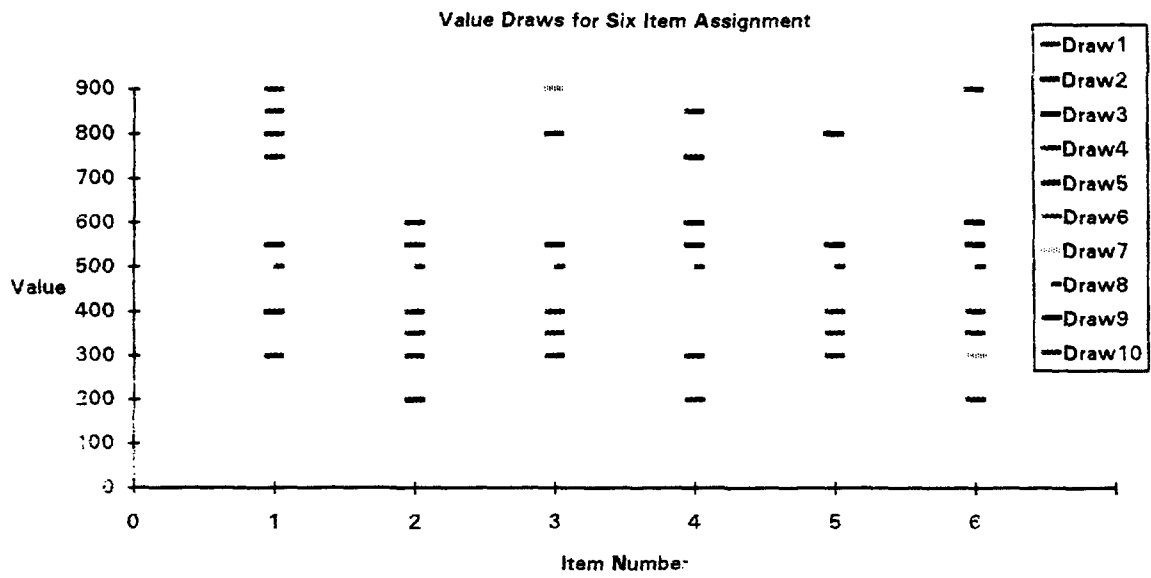Sequential Japanese Is Higher
(reflecting the pushing phenomena)

The Simultaneous Process Has an Efficiency Edge
<Efficiency by Period>

C=Collection Should Win
I=Individual items Should Win

Revenue Generated by Auctions

Value Draws for Six Item Assignment

Legend: Draw1, Draw2, Draw3, Draw4, Draw5, Draw6, Draw7, Draw8, Draw9, Draw10

Value (y-axis): 0 to 900

Item Number (x-axis): 0 to 6

Efficiency by Periods

Legend: Simultaneous, Serial Dictator, Sequential

Efficiency (%) (y-axis): 70 to 100

Periods (x-axis): 1--5, 6--10, 11--15, 16--20

Source: Olson and Porter